Fall 2001

Physics 129: Problem Set #10

Due Monday Dec 3 at 5PM

Homework Box available on 2^{nd} Floor LeConte breezeway

This is the last problem set of the semester

Note: For the problems on mixing in the K and B system, I use the formalism that is in J. Cronin's Nobel Prize lecture. That lecture is posted on our Web page.

1. Perkins 8.4

2. Perkins 8.7

3. Let's consider the semileptonic decay of neutral kaons

   (a) Show that the total decay rates for $K^0 \to \pi^- e^+ \nu_e$ and $\overline{K_0} \to \pi^+ e^- \overline{\nu_e}$ are equal if CP is conserved

   (b) If CP violiation occurs only through $|K_1\rangle$-$|K_2\rangle$ mixing, show that

   $$\Delta \equiv \frac{\Gamma(K_L \to \pi^- e^+ \nu_e) - \Gamma(K_L \to \pi^+ e^- \overline{\nu}_e)}{\Gamma(K_L \to \pi^- e^+ \nu_e) + \Gamma(K_L \to \pi^+ e^- \overline{\nu}_e)} = 2\mathrm{Re}\varepsilon$$

   You may ignore terms of order $|\varepsilon|^2$

4. Mixing has been observed in the neutral B system, as well as the K^0 system

   (a) Draw the box diagrams responsible for mixing in the B^0 and B_s^0 systems

   (b) The mass difference between the B_1 and B_2 is dominated by the case where the diagram you have drawn includes an intermediate top quark. Show that if you only consider this dominant diagram, the ratio of Δm for the case of the B_0 to Δm_s for the case of the B_s can be related to the ratio of the CKM matrix elements $|V_{td}/V_{ts}|$.

   (c) The size of the mixing can be described in terms of two parameters

   $$\Delta x = \frac{\Delta m}{\overline{m}} \text{ and } \Delta y = \frac{\Delta\Gamma}{\Gamma}$$

where $\overline{m}$ and Γ are the average mass and average inverse lifetime of the $|B_2\rangle$ and $|B_1\rangle$ states and Δm and $\Delta\Gamma$ are the differences in mass and lifetime. In the B system, y is small because there are a large number of states multibody final states avaiable both to the B and $\overline{B}$ decay. Hence there is no significant difference in the lifetimes of the two states. Suppose our state is produced as a B^0 (contains a $\overline{b}$ quark) at time $t = 0$. Show that the ratio of the decay probabilities:

$$\frac{\text{Prob}(B \to \overline{B} \to \ell^- X)}{\text{Prob}(B \to \ell^- X)} = \frac{x^2}{2 + x^2}$$

in the limit where y is zero. This expression indicates that it is possible, at least for some values of x to determine Δm without observing the time dependence of the mixing

(d) What are the curent measured values or bounds on x in the case of the B^0 and the B_s? Explain for each case whether a time integrated mixing measurement is a good method to use.

5. The LEP experiments have all searched for the Higgs boson. By looking at the latest results available on the Web, state what the current limits on the Higgs mass are from direct searches for Higgs production. What are the indirect limits on the Higgs mass obtained from analysis of the precision electroweak data from LEP and the Tevatron? Give the web references you used.